PERSPECTIVES FOR INVESTIGATIONS OF CHARACTERISTICS OF NUCLEAR INTERACTIONS AT ENERGIES OF 10^{11}-10^{13} eV ON THE LARGE INSTALLATION AT THE HIGH-ALTITUDE STATION "KUM-BEL'" OF THE INSTITUTE OF NUCLEAR PHYSICS OF THE ACADEMY OF SCIENCES OF THE UZBEK SSR

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ABSTRACT. A device for studying the characteristics of nuclear interactions, located at the "Kum-Bel'" high-altitude station, is described in detail, as is the method of its use for determining the effective cross-section of elastic interaction, the angular distribution of shower particles, and investigating other phenomena.

Introduction

A characteristic feature of nuclear interactions at high energies is /89 multiple particle production. Thus far however, there has not been any satisfactory theory of strong interactions which would describe multiple processes. The theories and models of multiple origin of particles that were proposed comparatively recently show little relation to one another and do not reflect all aspects of the phenomenon. In this connection, we feel that it is very important to have a detailed comparison of these theories with the characteristics of their interactions at high and medium energies. However, the accuracy of the experimental results which have been achieved thus far is not always sufficient for an unambiguous choice between the different theoretical treatments, and in many cases the data which are obtained in various laboratories contradict one another.

The purpose of the present paper is to evaluate the perspectives for investigation of such characteristics of interaction as the effective cross-section of inelastic interaction, the angular distribution of shower particles, the coefficient of inelasticity, multiplicity, direct generation of muons in powerful interactions with super high energies in the large installation at the cosmic-ray laboratory of the Institute of Nuclear Physics of the Academy of Sciences at Uzbek SSR.

Characteristics of the Nuclear Interactions

Effective cross-section of inelastic interaction. Measurement of the effective cross-sections of nucleon-nucleon and pion-nucleon interactions over a wide range of energies has been of considerable interest for the physics of elementary particles, inasmuch as there are different theoretical concepts in existence regarding the behavior of these cross-sections in the high energy region. Measurements of the cross-section of inelastic interactions of /90 nucleons with hydrogen nuclei σ_c, conducted on accelerators in the energy range up to 2.4×10^{10} eV [10] have given for the quantity σ_c a value which is very close to geometric ones (~220 mbarns). In the range of energies of $\sim 10^{11}$ eV the measurements made with the aid of cosmic rays showed with an accuracy of ~10% that the cross-section of interaction of nucleons with hydrogen and ion nuclei is also close to the value obtained with accelerators [2-5]. Experimental data on the effective cross-section in the range of energies of approximately 10^{12} eV and above is still more sparse and the measurement errors are great.

Interest in this problem has increased considerably following the appearance of the papers published by N. L. Grigorov and his associates with good statistical accuracy (on the order of 6% in the energy range of 10^{12} eV) with the aid of the artificial earth satellites "Proton 1" and "Proton 2" [6]. According to their data, the inelastic interaction cross-section of protons with hydrogen nuclei increases by approximately 20% with an increase in the proton energy from 2.4×10^{10} eV to 5×10^{11} eV. Such a comparatively rapid increase in the cross-section is difficult to explain within the framework of available theoretical concepts regarding strong interactions.

It is necessary to mention however that there are several methodological shortcomings associated with these experiments. Thus, the small thickness of the ionization calorimeter, equivalent to approximately three path lengths for the interaction L_{inter}, could lead to significant errors in measurement of the energy of the primary particles E_0 (according to [7], when measuring E_0 with a calorimeter having a thickness of 2.5 L_{inter} more than half of the energy in 20% of the cases passed beyond the limits of the calorimeter and remained unmeasured). In addition, the installation was unable to determine the

direction of movement of the primary particles and to isolate the location of their passage through the device, so that fringe effects might have influenced the results of measurement. Hence, for a final solution of this problem, it is necessary to have additional investigations of the interaction cross-section in the energy range from 10^{11}-10^{12} eV, and a confirmation of the relationship of the cross-section to the energy obtained in [6] would require an error of less than 10% in measuring σ at an energy of 10^{12} eV.

Angular distribution. Investigation of the angular distribution of shower particles gives important information regarding the nature of the nucleon-nucleon interaction at high energies. A detailed analysis of the angular distributions of streams in photoemulsions, interpreted as the result of the collision of **a nucleon** with a nucleon at energies on the order of $E_0 \sim$ $\sim 10^{12}$ eV, led Polish physicists to conclude that in the majority of cases the /91 distribution of departure angles of secondary particles Θ_i in coordinates $\lambda = -\log \tan \Theta_i$ has a "two-humped" character in the system of the center of inertia of the colliding particles. These experimental data form the basis of the fireball model according to which the presence of "humps" in the angular distribution of shower particles is explained by the formation and subsequent decay to π-mesons of two meson clusters. According to the data obtained by the Physics Study Group of the Academy of Sciences of the USSR, one fireball is produced at energies of $\sim 10^{11}$ eV. Obviously, the number of fireballs slowly increases with an increase in the collision energy. However, the hypothesis regarding fireballs has thus far not received any conclusive support. The reason for this is the lack of experimental material regarding the angular distribution of shower particles, especially at energies greater than 10^{12} eV. In addition, the method of determining the primary energy E_0 on the basis of the angular distribution of secondary particles is unreliable.

The coefficient of inelasticity and multiplicity as functions of energy E_0. The coefficient of inelasticity K or the amount of energy transferred in nucleon collisions to all secondary particles is an interesting characteristic of interactions at high energies. This value shows considerable fluctuation from one case to the next, but its average value is slightly dependent upon E_0 in the range 10^{10}-10^{12} eV. However, there is considerable scatter in the

absolute value of the coefficient of inelasticity given by various authors [9, 10, 11]. Thus, for the value $\overline{K}_{\pi 0}$, the average amount of energy transferred to neutral pions in the collision of nucleons with light nuclei, we obtained a value of 0.15 to 0.30. This can be explained by the difficulty of considering such methodological factors which affect the measurements of the energy of π^0 mesons as the contribution to ionization of nuclear fission within the walls of the chambers of ionizing calorimeters, secondary interactions in lead filters, indeterminacy of the coefficient, which accounts for the transition effect in the walls of the chamber, etc.

In the range of higher energies (10^{12}-10^{13} eV) we still have very little direct experimental data regarding the behavior of the inelasticity coefficient. Interest in this range of energies is explained by the fact that there are indirect indications of an increase in the inelasticity of the interaction in the energy range around 10^{13} eV, caused by the additional mechanism of energy transfer in the electron-photon component, called "gammanization" in contrast to the usual process of "pionization" [8].

The dependence of the multiplicity of secondary charged particles n_s upon /92
the energy is very interesting for comparison of theories and models of multiple origin of particles with experimental results. According to the hydrodynamic theory of Fermi and Landau, the multiplicity depends upon E_0 as

$$n_s \sim \left(\frac{E_0}{Mc^2}\right)^{1/4},$$

where M is the mass of the nucleon and c is the speed of light. On the other hand, it follows from the theory of peripheral interactions [12] that this relationship has the form

$$n_s \sim \ln \frac{E_0}{Mc^2}.$$

However the accuracy of the experiment is still insufficient for making a choice between these treatments. Inasmuch as the dependence of n_s upon E_0 is slight, it is necessary to make measurements over a very wide range of energies. The principal difficulty in this regard is to determine the primary energy and the lack of statistical material in the range of high energies (10^{12} eV).

In studying these characteristics of interaction at high altitude locations, it is also necessary to take into account the nature of the shower-generating

particles, which strike the apparatus. Obviously, showers that are formed in the target by neutral particles are produced by nucleons, while showers that are generated by charged particles can be produced both by protons and by $\pi^{\pm}$ mesons, the percentage of pions in the total flux of nuclear-active particles at high altitude level increasing with energy, reach ~30% in the energy range near 10^{12} eV. In this regard, it becomes possible to study the pion-nucleon interactions at very high energies by comparing the characteristics of the interactions produced by neutral and charged particles.

Direct generation of muons in nuclear interactions at high energy. On the basis of experimental data, collisions of nuclear-active particles with energies less than 10^{12} eV does not result in the formation of leptons with a cross-section comparable to the cross-section of generation of π-mesons. However, in the range of high energies, data has been obtained relating to the conditions of formation of π-mesons which is difficult to understand without applying some new concepts regarding the mechanism of formation of these particles. These experimental results include the first observations of limited groups of penetrating high energy particles in a Wilson chamber [13] and in the composition of broad atmospheric showers (B.A.S.) underground at a depth of 1,600 m water equivalent (M.W.E.) [14]. In later experiments performed by Japanese physicists with the aid of an underground Wilson chamber [15] and a group at Moscow University who used a complex device to study the broad atmospheric showers [16], additional information was obtained regarding the mechanism of formation of pairs and groups of particles at very high energies. To explain these results, several interesting hypotheses have been put forward. /93

For example, direct generation of leptons can occur as a result of conversion of weak interactions into strong ones in the super-high energy range. On the other hand, this phenomenon may be linked to the formation of new particles decaying in a very short time to μ-mesons.

Muons, photons and electron pairs can develop in a hydrodynamic process in the form of an additional electromagnetic radiation from a cluster of nuclear material, formed in the interaction of high energy nucleons [12, 17].

These explanations must be viewed only as working hypotheses for the sake

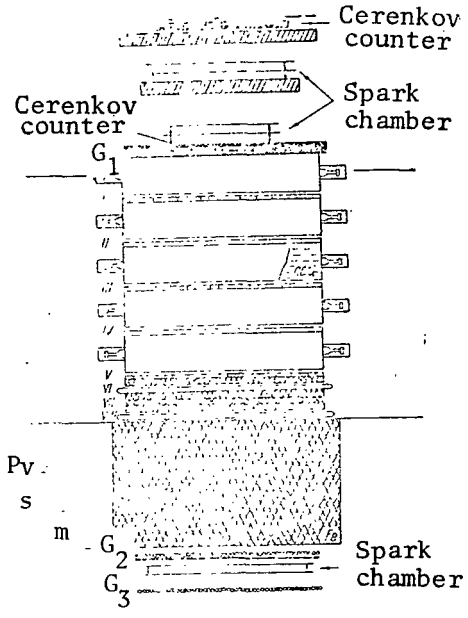
of orientation. In addition, the very fact of direct generation of μ-mesons in nuclear interactions has not yet been definitely confirmed. In the experiments which we mentioned, for example, the point of generation of the groups of particles still remains unclear, as does the nature of the particles in the group, their energy distribution, etc.

However, recent experiments conducted by a group of workers at Ithaca University, headed by J. Keufel, have evidently obtained some strong arguments in favor of the existence of the mechanism of a direct generation of μ-mesons in strong interactions [18]. The investigators, who used a large apparatus located beneath a mountain at a depth of approximately 2,000 M.W.E., studied the energy spectra of μ-mesons in the energy range of 5×10^{11}-10^{13} eV for various ranges of angles with the vertical. The angular distribution of muons of such energy was found to be nearly isotropic. This made it possible to conclude that the overwhelming majority of the muons with an energy of 10^{12} eV is formed in the process of direct generation. However, this conclusion was drawn from the basis of indirect data and further studies will be required for a final answer to the problem.

Apparatus

To study these interaction characteristics of energies 10^{11}-10^{13} eV a /94
device (see the Figure) with a high effective area equal to 9 m^2 was built at the high-altitude station "Kum-Bel'" of the Institute of Nuclear Physics of the Academy of Sciences of Uzbek SSR, located at an altitude of 3,200 m above sea level. The target consists of two blocks of carbon, each 20 cm thick. In order to obtain information regarding the angular distribution of secondary particles, the site of their formation and their passage through the device, two spark chambers are used. The upper one measures $30 \times 200 \times 200$ cm^3, and it is mounted on top of the first carbon target and 60 cm above it, being intended for determining the direction of incidence of nuclear-active particles on the device, estimating their air resistance and studying the angular distribution of shower particles formed in the first target. The lower spark chamber measures $30 \times 150 \times 150$ cm^3 and is 80 cm away from the second carbon target.

A thin Cerenkov counter is located beneath the spark chambers. It is shielded by a layer of lead which is equivalent to 7 radiation units. The



counter has an effective area of 1.5 m^2 and is made of double plexiglas sheets; the space between the latter is filled with magnesium oxide powder. Each of the two opposite walls of the counter is fitted with a type FEU-49 photomultiplier with a photocathode diameter of 150 mm. Optical contact between the cathode of the photomultiplier and the window of the Cerenkov counter is provided by glycerin. The radiator is ethyl alcohol, which is poured into the counter to the 7 cm level, so that the total thickness of the Cerenkov detector is ~6 g/cm^2. To absorb the /95 electron-photon component, which accompanies the nuclear-active particles, 10-cm layers of lead are placed around the thin Cerenkov counter, and one row of hodoscopic counters G_1 is placed beneath it.

This is followed by an energy detector composed of five rows of Cerenkov counters and eight rows of ionization chambers located between the Cerenkov detectors and layers of iron. In each row there are five Cerenkov counters which are metal tanks welded together from stainless steel and covered on the outside with a white reflecting material. The counters measure 60 × 60 × 300 cm^3 and are filled with distilled carbon tetrachloride. Cerenkov radiation is recorded by two type FEU-49 photomultipliers mounted in the end walls of the counters. The characteristics of such detectors are discussed in [19].

Between the Cerenkov counters are five rows of ionization chambers, type IK-6 (I-V) made of waveguides with a cross-section of 110 × 54 mm and 3 m long. The principal electrode in the chambers is a brass tube 3 mm in diameter. There are 25 ionization chambers in each row, with the axes of the chambers in adjacent rows being mutually perpendicular. Beneath the Cerenkov detectors there are

three more rows of cylindrical ionization chambers, type IK-8 (VI-VIII) shielded by layers of iron 10 cm thick. The diameters of the chambers of this type are 10 cm with a chamber length of 330 cm. A total of 30 chambers is contained in each row.

As the energy of the primary particles increases, the probability of their being accompanied by air showers is increased as well. To estimate the density of the particles of the latter, four thin Cerenkov counters are placed above the installation shielded by a 2 cm layer of lead. The counters are made of plexiglas sheets, with the space between being filled with magnesium oxide; they measure 10 X 100 X 100 cm^3. Distilled water serves as a radiator. The Cerenkov radiation is recorded by type FEU-43 multipliers, mounted in the side walls of the counters. The impulses from the FEU Cerenkov counters are summed and in the event of exceeding the amplitude of a set threshold value, they are fed into the anticoincidence channel of the control block for discrimination of events accompanied by extensive atmospheric showers.

Beneath the energy detector, in the cellar, there is an iron filter /96
weighing 200 tons. It is about 2 m high which amounts to ~1500 g/cm^2. The filter serves to absorb the nuclear-active particles and the electron-photon avalanches generated in the apparatus.

Beneath the filter is a μ-meson detector, consisting of two rows of Geiger counters G_2 and G_3, between which there is a layer of lead 2 cm thick and a spark chamber measuring 15 × 200 × 200 cm^3. Each row consists of 216 type SI-6G counters, enclosed in individual hodoscopic cells. The effective area covered by the hodoscopic counters of one row is 4 m^2.

Method of Measuring Energy of Primary Particles E_0

The principle difficulty in setting up experiments with cosmic rays is the irregularity of the energy of the primary particles. For a detailed investigation of the characteristics of the collision situation, it is necessary to have reliable and sufficient accuracy of measurement of the energy of incident particles. Suitable methods of estimating E_0 on the basis of the angular distribution of shower particles are based on the assumption of the symmetrical departure of particles in a center of inertia system, which does

not always hold. In addition, the fluctuations in the angular distribution of secondary particles in the case of a steeply falling primary energy spectrum leads to considerable errors in evaluation and to a systematic increase in the energy of the shower-generating particles E_0.

The method suggested comparatively recently by N. L. Grigorov, for an ionization calorimeter [20] free of any kind of assumptions regarding the angular distribution of secondary particles makes it possible to determine the energy of the primary particles with high accuracy. As we know, practically all the energy of the nuclear-active particle in a sufficiently thick layer of material changes to electron-photon component. Therefore, by measuring the number of particles at different depths in the absorber, we can determine the energy of the primary nuclear-active particles from the relationship

$$E_0 = \beta \int_0^\infty N(t)\,dt,$$

where N(t) is the number of particles in depths t in the absorber and β is the critical energy for a given substance.

The ionization calorimeter makes it possible to measure very large particle energies, where the accuracy of measurement increases with increasing E_0. /97 The transmission of such devices is great, and the use of a large number of ionization chambers makes it possible to determine the site of occurrence of clusters of showers in the device.

However, in some cases strongly-ionizing particles from nuclear fission can form "bursts" in ionization chambers, equivalent to a large number of relativistic particles, causing considerable errors in the measurement of primary energy. There is also a certain amount of indeterminacy in plotting the curve of the absorption of the particle flux in the calorimeter material.

On the other hand, the slanting front of impulses from ionization chambers (~10 microseconds) creates considerable difficulties in the joint operation of spark chambers with an ionization calorimeter.

Cerenkov spectrometers with complete absorption are free of these shortcomings. The contribution to the Cerenkov radiation is made only by relativistic particles, and the energy is measured directly on the basis of the total energy output of the particles in the radiator of the Cerenkov detector,

and the length of the leading front of the impulses caused by the accumulation time of the luminescence on the photomultiplier, has a low value of $\sim 10^{-8}$ to 10^{-7} sec, even for detectors with a very large volume.

If the electromagnetic shower is fully developed in the Cerenkov spectrometer, the total path length of the electrons will be proportional to the expended energy. The condition of proportionality consists in the fact that the average path of shower particles with an energy above E_{thresh} integrated with respect to the volume of the Cerenkov detector should be a linear function of energy of the primary particle E_0. This condition is fulfilled sufficiently well if the critical energy for the radiating substance is much greater than E_{thresh} of the Cerenkov radiation. For carbon tetrachloride $\beta \cong 40$ MeV, $E_{thresh} \cong 0.2$ MeV. The use of CCl_4 with a specific gravity $d = 1.65$ g/cm^2 and an average atomic number $\bar{z} = 16$, corresponding to a radiation length $t_0 = 20$ g/cm^2, makes it possible to build a spectrometer that is more compact than in the case where water is used. This results in an increase in the number of radiating units in the spectrometer, which is of considerable importance for complete development of cascade showers with high energy. The total thickness of the Cerenkov spectrometer in this device is 500 g/cm^2, equivalent to ~ 5 /98
passages for interaction.

The shortcomings of Cerenkov's spectrometers for complete absorption include a poor spatial resolution of the clusters of showers and difficulty in distinguishing cases of simultaneous passage through the apparatus of several nuclear-active particles.

We proposed and incorporated in this apparatus a combined method which made it possible to measure the energy of nuclear-active particles simultaneously by two independent methods, considerably increasing the reliability of determination of E_0. The energy detector, which consists of a Cerenkov spectrometer for total absorption and is made up of stacked layers of ionization chambers, is designed in the form of a stand with eight steel frames welded to it, in which the type IK-6 and IK-8 ionization chambers are mounted. Between the five rows of ionization chambers, there are five Cerenkov detectors which together make up a Cerenkov spectrometer for total absorption. The eight rows of ionization chambers constitute a unique spatial coordinate system which makes

it possible to define clearly the site of passage of the cores of the showers which are formed by incident particles in the apparatus. The filter for the ionization calorimeter is the radiator material in the Cerenkov detectors.

Additional iron filters with three rows of ionization chambers served to estimate the amount of primary energy which is carried beyond the limits of the Cerenkov spectrometer. The total thickness of the energy detector is equal to ~7.5 passages for interaction.

Thus, the above described energy detector combines the advantages of the Cerenkov total-absorption spectrometer and the ionization calorimeter.

Method of Investigation of Interaction Characteristics

Measurement of the effective cross-section of inelastic interaction of high energy particles with hydrogen nuclei was performed by the method of "knock-on from the beam." If N_0 is the flux of nuclear-active particles incident on the apparatus and N_1 is the counting rate for the recorded nuclear interactions, then

$$N_1 = wN_0,$$

where w is a value which takes into account the probability of interaction of the incident particles and the geometric factor of the apparatus. When a graphite filter with a thickness of X_c is placed above the apparatus, the counting rate is equal to /99

$$N_2 = N_1 e^{-\frac{X_c}{L}},$$

where L is the path for inelastic interaction.

From these relationships we will find

$$L = \frac{X_c}{\ln\left(\frac{N_1}{N_2}\right)},$$

when the section of inelastic interaction will be equal to

$$\sigma_c = \frac{A}{X_c N} \ln\left(\frac{N_1}{N_2}\right),$$

where A is the number of nucleons in the nucleus and N is Avogrado's number.

This method is obviously very reliable and satisfactory for measuring the interaction cross-sections, since the effectiveness of recording the showers remains unchanged when a filter is placed over the apparatus. The site

of passage of showers within the limits of the solid angle of the apparatus is determined with the aid of spark chambers, located between two carbon blocks. Periodic changing of the filter above the upper spark chamber is accomplished with the aid of a movable platform on which the first carbon target with a thickness of 20 cm is mounted. We selected for analysis those showers which were generated in the second target by particles that had passed through the first target without interaction.

Since we had not yet finished developing in the laboratory a system for recording the impulses from the ionization chambers under the conditions of high voltage noise which develop during the operation of spark chambers, we used only the Cerenkov spectrometer with total absorption in the first series of measurements for determining E_0.

The geometric factor of the apparatus is $\sim 1.1\ m^2$ per steradian. According to [21], the absolute intensity of the nuclear-active particles with energies $E_0 > 5 \times 10^{11}$ eV at an altitude of 3,200 m above sea level is $N_0 \cong 2\ m^{-2} \cdot hr^{-1} \cdot sr^{-1}$. Then, if we assume that $L = 85\ g/cm^2$, we will find that the expected frequency of the recorded events in the absence of an upper target amounts to

$$N_1 \cong 0{,}6\ hr^{-1}$$

with a target having a thickness $X_c = 32\ g/cm^2$, $N_2 = 0.4\ hr^{-1}$.

It is obvious that not all recorded events can be included in the analysis /100 due to the considerable probability of entrainment of nuclear-active particles in the energy range $\sim 10^{12}$ eV. According to [22], in 30% of the cases occurring at high altitude the nuclear-active particles with $E_0 > 300$ GeV are accompanied by air showers at distances of less than 0.5 m. If we discard the events in which the shower-generating particle is accompanied by other particles at distances greater than 0.5 m, the values N_1 and N_2 must be reduced by a factor of 1.5. Obviously, the showers which are selected on the basis of such criteria will be suitable for analysis.

It was shown in [23] that the entrainment of nucleons with energies >100 GeV at an altitude of 3,200 m above sea level has a density of $\sim 20\ m^{-2}$ and consists primarily of mesons with an energy of several GeV. The entrainment of this type will introduce insignificant error into the energy measurement in the range $E_0 > 500$ GeV.

The energy of the primary particles can be increased with simultaneous incidence on the apparatus of several particles of comparable energy. However, the use in the apparatus of a Cerenkov spectrometer consisting of five independent parts (each 0.6 × 3.0 m^2 in area) significantly reduces the probability of the incidence on an individual part of the spectrometer of a group of nuclear-active particles. These factors may be readily taken into account with simultaneous operation of a Cerenkov spectrometer with an ionization calorimeter in the energy detector.

Hence, after 2-3 months of operation of the apparatus it is possible to measure the cross-section of inelastic interaction of cosmic particles with hydrogen nuclei with an error which does not exceed 7-8% in the energy region of $\sim 10^{12}$ eV.

In the future, with an eye toward accomplishing joint operation of the ionization calorimeter with spark chambers, it is proposed to increase the "memory" of the spark chambers to 10-15 microseconds by adding ethyl alcohol to the gas in the chambers. It will then be possible to record the pulse from the ionization chambers and also to supply a high voltage pulse electrodes of the spark chambers. This will not produce any significant deterioration of the track quality or the effectiveness of recording in chambers with large discharge intervals [24].

The information received from the spark chambers is also used to study the angular distribution of the shower particles in the energy region of $\sim 10^{12}$ eV. The spark chambers are mounted at a sufficient distance from the targets so /101
that the spatial resolution of two particles simultaneously striking the spark chamber is not worse than $\sim 3 \times 10^{-3}$ rad.

The spark chambers are photographed in two mutually perpendicular directions. The photographs are analyzed by the re-projection method [25]. In the second series of measurements, in order to study the characteristics of nucleon-nucleon interactions, the carbon targets were replaced by a single target composed of LiH, 0.2 L thick. It was expected that after 2,000 hours operation of the device, approximately 200 nucleon-nucleon interactions in the energy region of $\sim 10^{12}$ eV would be recorded.

Another interaction characteristic which was studied with the aid of this apparatus in the energy range of 10^{11}-10^{13} eV is the inelasticity coefficient for the formation of π^0-mesons $K_{\pi 0}$, defined as the ratio of the energy transmitted in the interaction of all π^0-mesons $E_{\pi 0}$, to the total energy of the shower-generating particles E_0

$$K_{\pi^0} = \frac{E_{\pi^0}}{E_0}.$$

The value $E_{\pi 0}$ is estimated on the basis of the number of electrons in the area of the maximum development of cascade showers, which developed as the result of decay of π^0-mesons to γ-quanta.

The number of particles in the vicinity of the maximum is measured with the aid of a thin Cerenkov counter, mounted beneath seven radiation units of lead. For a more precise measurement of the number of particles in the vicinity of the maximum of cascade showers, we will in the future cover the thin Cerenkov counter with an additional two layers of ionization chambers, shielded by lead filters. Then, selecting the pure electron-photon showers that strike the apparatus, we can compare the readings of the Cerenkov counter with the data obtained with the aid of ionization chambers. It is interesting in this regard to compare the distribution of $K_{\pi 0}$ and n_s, obtained for neutral and charged particles with the aid of a study of a mechanism of pion-nucleon interactions.

In order to study the groups of penetrating particles that are generated in high-energy interactions, we use a μ-meson detector, composed of two rows of hodoscopic counters and a spark chamber. The total number of materials above the detector for μ-mesons amounts to ~20 passages for interaction. In order to increase the statistical material in the high energy region of $\sim 10^{13}$ eV, we shall record the showers which are formed both in the upper filters above the apparatus and in the first layers of the Cerenkov detectors of the spectrometer. We shall select for analysis those events which are associated with the /102
passage of groups of penetrating particles through the detector for μ-mesons. It is necessary in this regard that the direction of the tracks of the penetrating particles coincide with the axes of the showers which are produced in the energy detector. After one year of operation of the device, it is expected that approximately 100 showers with energies $>10^{13}$ eV will be recorded. In

addition, we shall add a multiple-layer system of proportional counters, alternating with lead filters, to estimate the energy of the penetrating particles in the groups of μ-meson detectors.

The plans for using this apparatus to study the structure of the cores of wide atmospheric showers are interesting. For this purpose, the apparatus will be expanded by adding several groups of hodoscopic counters and Cerenkov detectors mounted at various distances from the apparatus in order to determine the sites of passage of the core of a broad atmospheric shower and the number of particles at the level of the observer. In studying the cores of broad atmospheric showers, it is possible to obtain simultaneous information regarding the energies of electron-photon and nuclear-active components, the number of μ-mesons in the cores of the broad atmospheric showers, and the groups of penetrating particles in them.

Thus, with the aid of the apparatus at the high altitude station "Kum-Bel'" of the Institute of Nuclear Physics of the Academy of Sciences of Uzbek SSR, it will be possible to obtain important information regarding the interaction characteristics of nuclear-active particles at high and super-high energies.

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